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Research Article

Development of technology for modified starch incorporated grains and pulse blended bakery and pasta products

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Abstract
The study aimed to investigate the appropriate technology for the development of modified starch and standardize the millet-based bakery and pasta products incorporated with modified starch and measure the glycemic index of the standardized therapeutic baked and pasta products. The physical modification and chemical modification techniques were performed to optimize the technology for modified starch. Refined wheat flour was substituted with millet flour, modified starch and pulse flour at various percentages to optimize the flour blend for pasta and bakery products. The products were subjected to *in vitro* study to measure the glycemic index. Physical modification technique, i.e. autoclave-cooling, was found to be optimum for the development of modified starch. The optimum flour blend for pasta products was whole wheat flour(50%), millet flour (25 and 50%), cassava modified starch (15 and 25%) and green ram flour (10%) and it was found to be acceptable without affecting its sensory attributes. The optimum blend for bread was whole wheat flour (50%), kodo / barnyard millet flour (50%) with cassava modified starch (10%) and for low-fat cookies, it was millet flour (20%) and modified starch (15 %). Among the three pasta products, noodles and macaroni were found to be highly acceptable with minimum cooking loss. The *in vitro* study showed that the pasta products have a hypoglycemic effect suitable for lifestyle disorder patients and do not involve high production costs and earn good returns to the entrepreneurs.

Keywords: Autoclave-cooling, Glycemic index, Millet incorporated pasta products, Modified starch

INTRODUCTION

Health and nutrition are the most demanding and challenging field in this era and would continue to be in the future. There is considerable public interest in the capacity of foods and food components to promote health and lower risk of non-infectious diseases related to diet and lifestyle. Diet and lifestyle-related diseases include coronary heart disease, certain cancers (e.g. large bowel), inflammatory bowel diseases (IBD) and diabetes (International Diabetes Federation, 2009). Functional foods have two general types of beneficial effects: to reduce the risk of disease and to enhance a specific physiological function. The incidence of *diabetes mellitus* is increasing in an exponential manner globally. Diabetes mellitus is possibly reaching epidemic proportions in India. There are large dissimilarities in diabetes prevalence between states in India. As stated by a recent systematic review based on the statistics from ICMR-INDIAB, the overall prevalence of diabetes in 15 states of India was 7·3 per cent. The etiology of diabetes in India is complex and includes genetic factors coupled with environmental impacts such as obesity-associated with the rising standard of comfort, constant urban migration, and lifestyle changes (Kaveeshwar and Cornwall, 2014). Murtaugh *et al.* (2003) reported that consumption of diets rich in whole grains reduced the incidence of type 2 diabetes. Marilena *et al*. (2020)

studied the dietary habits and the association with glucose control, measures of adiposity, and major cardiovascular risk factors. Higher pasta consumption was associated with a lower intake of proteins, total and saturated fat, cholesterol, added sugar, and fiber. Glucose control, body mass index, prevalence of obesity, and visceral obesity were not significantly different across the quartiles of pasta intake. No relation was found with LDL cholesterol and triglycerides, but there was an inverse relation with HDL-cholesterol. Systolic blood pressure increased with pasta consumption; but this relation was not confirmed after correction for confounders. Conclusions: In people with type-2 diabetes, the consumption of pasta, within limits recommended for total carbohydrates intake, is not associated with worsening of glucose control, measures of adiposity, and major cardiovascular risk factors. The research findings showed that the development of pasta and bakery products with lower GI and low energy density by adding modified starch with high resistant starch content was the most promising solutions to decrease the prevalence of metabolic disorders. The aim of the present study was i) to optimize the technology for the development of modified starch from cassava with a high amount of resistant starch by physical method, ii) to develop the low glycemic pasta and low-fat cookies from grain and millet substituted pulse and modified starch.

MATERIALS AND METHODS

Freshly harvested cassava (*Manihot esculenta),* raw green banana (*Musa paradisiaca*), and maize (*Zea mays)*, Whole wheat (*Triticum aestivum*),kodo millet (*Paspalum scrobiculatum),* barnyard millet (*Echinochloafrumentacaea),* little millet, finger millet, green gram dhal (*Vigna radiate),* commercially available sodium alginate, guar gum (Food grade), yeast, baking powder, flavouring agents were collected from departmental stores and utilized for product formulations. High molecular High-density Polyethylene bags (HMHDPE) (20 x 24.5 cm) of 80 gauge and metallised polyester / polyfilm laminated bags (20 x 24.5 cm), were used for shelf stability assessment

Standardization of optimization technology for the development of resistant starch from cassava, banana and maize:

To optimize the technology for the development of modified starch which was utilized as the functional food ingredient for preparation of low glycemic bakery and pasta foods, physical and chemical modification methods were adopted. The physical modification (autoclaving - cooling cycle method) technique was followed for the preparation of modified starch (cassava, banana and maize) as per the standard of Berry (1986) procedure with slight modification. The maize, cassava and banana native starch were mixed with water. Then it was pressure-cooked at 121˚C (15 lb / in^2) for one hour in an autoclave. The gelatinized starch mixture was cooled to room temperature and was freezed at 4˚C for 24 hours, termed as one cycle. The three additional cycles were then carried out, followed by cabinet-drying for about 4-6 hours at 40ºC according to the respective starches and ground into fine particles. The Chemical modification - acid hydrolysis technique was carried out for the preparation of modified starch (cassava, banana and maize) as per the method followed by Chatakanonda *et al*. (2011) with slight modification.

The per cent recovery of modified starch was determined by comparing it with the dry weight of the native starch. The modified starch yields obtained were recorded for the above two methods. The results show that the physical modification– autoclaving and cooling cycle method could be standardized as the technology for the development of resistant starch. The per cent recovery of modified/ resistant starch was determined by comparing it with the dry weight of the native starch (Ji *et al*., 2004). The physical characteristics like colour, solubility index and swelling power, water binding capacity and gelatinization time and temperature were examined for native and modified starch. Chemical characteristics such as moisture, pH, acidity, ash, carbohydrate, protein, fat, calcium, iron, starch, crude fiber, amylose, amylopectin and resistant starchof native and modified starch were analyzed in the study.The moisture content of the samples was determined as per the method described by Ranganna (1995). The pH and acidity of the samples were estimated by the method as described by Saini *et al.* (2001). Carbohydrate was estimated by the phenol sulphuric acid method described by DuBois *et al.* (1956). Protein was analysed by the amount of nitrogen available in the sample as described by Ma and Zuazaga (1942). The fat content of the sample was estimated by the solvent extraction method as described by Cohen (1917). Calcium was estimated by titration method as described by Clark and Collip (1925). Iron content was estimated by the Colorimetric method as described by Wong (1928). The starch content of the sample was estimated using anthrone reagent described by Thayumanavan and Sadasivam (1984). The crude fiber content was determined by the method as described by Maynard (1970). The sample's amylose and amylopectin were estimated using the iodometry method (McGrance *et al.,*1998). Resistant starch type 3 was isolated by a modification of the Association of Official Analytical Chemists (AOAC) Official Method 2002.02.

Standardisation of low glycemic functional pasta products (Noodles)

Among the three modified starch, cassava modified starch was utilized to develop low glycemic functional pasta products because of its ease in starch extraction, per cent recovery (yield), low cost, and abundant availability. To standardize the formula for the preparation of pasta products like noodles, spaghetti and macaroni, various combinations of treatment schedule as trial was experimented. The refined wheat flour was replaced by whole wheat flour with combinations of kodo millet / barnyard millet flour and green gram dhal flour at different levels incorporated with modified/resistant starch (from 15% up to 25%) to formulate low glycemic functional flour for pasta products production were carried out. To improve the quality of the low glycemic pasta products such as strength, elasticity, and avoid disintegration and reduce solid loss, the Sodium alginate (NDL) / Guargum, a food stabilizer thatalso acts as a dietary fiber was added. The combinations of whole wheat flour, millet flour, pulse flour and modified starch for various treatments are shown in Table 1.

Formulation and preparation of low fat cookies

Low-fat cookies were prepared by incorporating kodo millet, little millet and foxtail millet flour each at 25, 50 and 75 per cent levels, as given in Table 2. The functional ingredient wheat flour was replaced by millet flour and all other basic ingredients remained the same.

Quality assessment of developed products:

Physico-chemical characteristics of the starch and functional pasta (noodles)

The physical characters, such as colour value, solubility, swelling power, water binding capacity and resistant starch content, were analysed. The chemical characteristics such as moisture, protein, fat content, starch, amylose, total fibre content, soluble dietary fibre, insoluble dietary fibre, calcium, iron and phosphorus were assessed.

Sensory evaluation of pasta and low fat cookies

The pasta and low fat cookies were organoleptically evaluated by using a panel of ten untrained judges at regular intervals. The standardized low fat cookies were packed in 200 gauge Poly Propylene pouches and 600 gauge Plastic containers to assess the sensory attributes at an interval of 15 days by a panel of members using nine point hedonic scale as per the method described by Watts *et al*. (1989). The organoleptic evaluation sessions were conducted one hour before lunch under adequate conditions of temperature, humidity and illumination.

Animal experimental protocol

The animal experiments were approved by the Institution of Animal Ethics Committee, KMC College of Pharmacy, Madurai. In the experiment, a total of 54 rats (48 diabetic surviving rats and six normal rats) were used. Diabetes was induced in rats three days before starting the experiment. The rats were divided into eight groups (each group consist 6 rats)after the induction of 150 mg/kg of alloxan monohydrate through I.P. diabetes. In the experiment, six rats were used in each group.

Treatment protocol

Group –I(Normal control): It consisted of normal rats given with 10 ml/kg of normal saline with normal diet.
Group - II (Diabetic control): It received a normal diet.
Group - III: (Treatment control group) It received whole wheat flour noodle (T1) for 28 days.
Group - IV: (Treatment group) It received whole wheat flour + kodo millet flour noodle (T2) for 28 days.
Group - V: (Treatment group) It received whole wheat flour + kodo millet flour + cassava modified starch noodle (T3) for 28 days.
Group - VI: (Treatment group) It received whole wheat flour + kodo millet flour + cassava modified starch + green gram dhal flour noodle (T4) for 28 days.
Group - VII: (Treatment group) It received whole wheat flour + barnyard millet flour noodle (T5) for 28 days.
Group - VIII: (Treatment group) received whole wheat flour + barnyard millet flour + cassava modified starch noodle (T6) for 28 days.
Group - IX: (Normal group) It received whole wheat flour + barnyard millet flour + cassava modified starch + green gram dhal flour noodle (T7) for 28 days.

Statistical analysis

Data of starch and animal experiments collected from all experiments were replicated three times were expressed as means ± standard deviations. Data were analyzed using Data Entry Module for Agres Statistical Software (Version 3.01) developed by Tamil Nadu Agricultural University, Coimbatore. The data obtained from the various experiments were subjected to statistical analysis to find out the impact of different treatments and storage period on the quality of the stored pasta products by using Completely Randomized Design (CRD) method as described by Cochran and Cox (1957). For animal experiments, all the values were expressed as mean ± SEM. Data was analyzed by one way analysis of variance (ANOVA) followed by Newmankeuls multiple tests. P values <0.05 were considered as statistically significant.

RESULTS AND DISCUSSION

Native starch isolation process on cassava, banana and maize

In the present investigation, the data of the native starch from the raw food materials such as cassava

Table 1. Proportion of functional flour used for low glycemic pasta products (noodles) formulation.

Treatment	Whole wheat flour (%)	Kodo millet flour (%)	Barnyard millet flour (%)	Cassava modified starch (%)	Green Gram flour (%)	Sodium alginate (%)
T_1 (Control)	100	---	---	---	---	---
T_2	50	50	---	---	---	
T_3	50	25	---	25	---	
T_4	50	25	---	15	10	
T_5	50	---	50	---	---	2
T_6	50	---	25	25	---	
T_7	50	---	25	15	10	

Table 2. Formulation of millet flour incorporated low fat cookies.

	Control	Kodo millet (T_1)			Little millet (T_2)			Foxtail millet (T_3)		
	100	**25**	**50**	**75**	**25**	**50**	**75**	**25**	**50**	**75**
Refined wheat flour (g)	100	75	50	25	75	50	25	75	50	25
Kodo millet flour (g)	-	25	50	75	-	-	-	-	-	-
Little millet flour (g)	-	-	-	-	25	50	75	-	-	-
Foxtail millet flour (g)	-	-	-	-	-	-	-	25	50	75
Modified starch (g)		10	10	10	10	10	10	10	10	10
Powdered sugar (g)	30	30	30	30	30	30	30	30	30	30
Vanaspathy (g)	40	40	40	40	40	40	40	40	40	V
Baking powder (g)	2	2	2	2	2	2	2	2	2	2
Corn flour (g)	3	3	3	3	3	3	3	3	3	3

Table 3. Starch yield and percent recovery / yield of modified starch

Source	Starch yield (%)	Physical modification (autoclaving-cooling cycle) (%)	Chemical modification acid hydrolysis(%)
Cassava	18.40 ±0.73	95 ± 0.56	36 ± 1.45
Banana	9.00 ±0.18	92 ± 0.64	31 ± 0.24
Maize	16.00 ±0.14	91± 1.12	26 ± 0.10

roots, raw banana and dry maize kernels isolated at laboratory scale by adopting specific corresponding native starch extraction techniques during starch extraction are presented in Table 3.

The highest percentage of starch yield was recorded to cassava (18.4%) followed by maize (16.0%) and banana (9.0%) starch. The per cent yield of modified starch recorded for physical modification (autoclaving- cooling cycle) technique was 95±0.56 per cent which was higher than the chemical- acid modification technique (36.0±1.45 per cent) from the native cassava starch. For banana and maize, it was recorded as 92.0±0.64 and 91.0±1.12 and 31.0±0.24 and 26.0±0.10 per cent for physical modification (autoclaving - cooling) technique and chemical - acid modification technique, respectively. The highest per cent recovery / yield were obtained for physical modification (autoclaving-cooling cycle) technique irrespective of all starch (cassava, banana and maize). Less starch yield was obtained with acid hydrolysis (chemical modification) as smaller water-soluble molecules were produced. During the physical modification (autoclaving-cooling cycle) technique, when autoclaved at 121°C, the starch was completely gelatinized. Amylose was leached from the granules into solution as a random coil polymer, whereas the crystalline regions of clusters of branched amylopectin chains had disappeared.

Physico-chemical characteristics of native and modified starches

Colour value, solubility (%), swelling power (g/g) and water-binding capacity (%) of native and modified starch are presented in Table 4.

The native cassava starch showed the highest values

Table 4. Colour value, solubility (%), swelling power (g/g) and water binding capacity (%) of native and modified starch.

Source	Starch	Hunter colour values (Scales)			Solubility (%)	Swelling power (g/g)	Water binding capacity (%)
		L*	a*	b*			
Cassava	Native	87.49	- 0.21	10.92	14.60±0.12	9.91±0.10	79.81±1.51
	Modified	64.22	-1.98	8.67	4.00± 0.03	4.64±0.16	86.46±0.42
Banana	Native	67.89	2.65	17.36	11.60±0.46	7.32±0.08	84.67±0.26
	Modified	57.09	2.80	14.84	2.90±0.09	4.77±0.32	88.56±0.43
Maize	Native	74.98	- 0.26	19.36	22.64±0.22	18.40±0.12	72.45±0.53
	Modified	70.36	- 0.36	16.38	14.10±0.38	11.45±0.51	77.56±0.44

Table 5. Resistant starch content of cassava starch.

Starch	Resistant starch content (%)
Native	2.37±0.07
Modified	8.12±0.08
SED	0.0651
CD (0.05)	0.1809**

for the luminosity parameter L* as 87.49 ± 0.76 and reduced to 64.22 ± 1.20, indicating a decrease in luminosity after modification. The native cassava starch showed higher values for the chromaticity coordinate b* (10.92 ± 0.34). The modified cassava starch reduced the yellowness as 8.67 ± 0.47. Chroma a* values recorded as -0.21 ± 0.06, 2.65 ± 1.44 and -0.26 ± 0.08 for native and -1.98 ± 0.94, 2.80 ± 0.65 and -0.36 ± 0.11 for cassava, banana and maize modified starch. When compared to cassava and maize starch, the luminosity of banana starch was low (67.89 ± 0.77and 57.09 ± 0.31) due to slight darkness. The native cassava starch showed the highest values for the luminosity parameter L* as 87.49 ± 0.76 and reduced to 64.22 ± 1.20, indicating a decrease in luminosity after modification. The high luminosity of cassava starch results from the weak associative bonds between starch molecules in the granules (Moorthy, 2002). The solubility decreased after modification and the modified cassava starch had 4.00 ± 0.03 per cent of solubility. Banana and maize showed 2.90±0.09 per cent had 14.10 ± 0.38 per cent of solubility. Waliszewski *et al*. (2003) recorded banana native starch solubility index and swelling power as 8.7 (g water g^{-1} dry starch × 100) and 8.7 (g water g^{-1} dry starch × 100). Kayisu *et al*. (1981) also reported that the *valery* banana starch had swelling power and solubility significantly lower than those of tapioca starch which is in conformity to the present investigation. The swelling power of modified starch was found to be less than the native starch. The water-binding capacity of

Table 6. Proximate composition of low glycemic pasta (noodles).

Particulars	T1	T2	T3	T4	T5	T6	T7
Moisture (%)	8.20± 0.15	8.17± 0.09	8.15± 0.13	8.13± 0.03	8.15 ±0.10	8.11± 0.13	8.08± 0.13
Protein (%)	11.14±0.13	10.82±0.21	9.26 ±0.22	11.20±0.05	11.12±0.23	9.34± 0.23	11.45±0.22
Fat (%)	2.10±0.007	1.92 ± 0.01	1.72± 0.04	1.70± 0.02	2.0 ± 0.03	1.75± 0.02	1.73± 0.03
Fibre (%)	2.00±0.04	5.21±0.12	5.83±0.08	5.60±0.10	6.62±0.14	6.91±0.17	6.84±0.12
Starch (%)	54.60 ± 1.40	43.92± 0.89	51.58 ±1.20	45.28± 1.06	41.70 ±1.01	50.12± 1.04	42.72± 0.88
Amylose (%)	21.40 ±0.30	16.45± 0.27	25.34± 0.32	21.60 ±0.32	17.10 ±0.15	26.10± 0.62	22.11± 0.39
Soluble Dietary Fibre (%)	2.20± 0.01	4.16± 0.04	4.04± 0.03	4.11± 0.10	2.30 ±0.02	2.00 ±0.001	2.19± 0.01
Insoluble Dietary Fibre (%)	8.20 ±0.13	11.09± 0.05	15.11± 0.21	14.74± 0.02	11.61± 0.13	15.63± 0.33	15.14 0.29
Total Dietary Fibre (%)	10.40± 0.19	15.25± 0.14	19.15± 0.47	18.85± 0.07	13.91± 0.18	17.63± 0.02	17.33± 0.22
Calcium (mg)	38.0± 0.91	41.00± 0.08	37.00± 0.01	43.00 ±1.09	37.50± 0.01	33.00± 0.49	40.00 ±0.33
Iron (mg)	4.42± 0.05	3.73± 0.04	3.20 ±0.01	4.07± 0.04	8.01 ±0.02	5.11± 0.011	6.13± 0.15
Phosphorus (mg)	297.0 ±0.52	242.5± 1.38	195.5± 2.03	245.0± 4.20	288.5± 2.10	218.5± 0.11	294.4 ±2.91

Treatments T1 to T7 mentioned in Table 1

Table 7. Sensory evaluation of the millet incorporated low fat cookies.

Varieties	Incorporation levels (%)	Sensory attributes				
		Color and appearance	Flavor	Texture	Taste	Overall acceptability
T_1	25	8.5	8.6	8.5	8.4	8.4
	50	8.6	8.7	8.6	8.5	8.5
	75	8.1	8.0	7.9	7.5	7.6
T_2	25	8.3	8.4	8.2	8.3	8.2
	50	8.5	8.6	8.4	8.5	8.4
	75	8.1	8.2	8.1	8.2	7.8
T_3	25	8.1	8.0	8.1	8.0	8.1
	50	8.4	8.3	8.2	8.3	8.3
	75	8.0	7.5	7.6	7.6	7.7

Treatments T1 to T3 mentioned in Table 1

Table 8. Effect of functional pasta products (noodles) on glucose level of normal and alloxan - induced albino rats.

GROUPS	0^{th} DAY	14^{th} DAY	28^{th} DAY
GROUP I (G 1)	80.55 ± 3.12	79.60 ± 3.50	78.45 ± 4.50
GROUP II (G 2)	155.70 ± 3.75	172.30 ± 8.20**(a)	220.53 ± 7.43**(a)
GROUP III (G 3) T_1	159.42 ± 3.95	132.52± 4.48**(b)	124.34± 4.57**(b)
GROUP IV (G 4) T_2	183.78 ± 3.58	154.72± 4.05**(b)	112.10± 3.57**(b
GROUP V (G 5) T_3	204.78 ± 3.60	185.76± 3.90**(b)	115.70± 4.37**(b)
GROUP VI (G 6) T_4	189.50 ± 3.75	141.32± 3.92**(b)	106.12± 4.16**(b)
GROUP VII (G 7) T_5	191.42 ± 3.85	154.64± 3.42**(b)	122.47± 4.74**(b)
GROUP VIII (G 8) T_6	196.33± 4.45	143.44± 2.62**(b)	109.94± 3.37**(b)
GROUP IX (G 9) T_7	195.12 ± 3.45	168.24± 3.48**(b)	108.29± 4.40**(b)

G1- Normal Control; G2- Diabetic Control; G3- Treatment control group T_1; G4- Treatment group T_2;G5- Treatment group T_3; G6- Treatment group T_4;G7-Treatment group T_5; G8-Treatment group T_6;G9-Treatment group T_7.

cassava, banana and maize modified starch (86.46±0.42, 88.56±0.43 and 77.56±0.44 %) was high when compared to its native starch. The water-binding capacity of modified starch was highest due to the high amylose content of RS3. It is known that amylose has a higher water-binding capacity than native starch.

Resistant starch content

The resistant starch content of native starch was recorded as 2.37 ± 0.07 per cent. After modification with three cycled autoclaving - cooling, it was improved to 8.12 ± 0.08 per cent, thus enhancing the therapeutic value and functional properties of cassava modified starch. Thus, the cassava resistant starch had been increased to 3.4 times than to that of native starch. According to Faridah *et al*. (2012), the starch hydrolysis process of arrowroot starch was continued with autoclaving-cooling (3 cycles) and could increase the dietary fiber and RS contents up to 4.1 4.4 times, respectively, than native starch. Arrow root resistant starch (RS) was obtained through 3 cycle(s) of autoclaving-cooling treatment of starch with different gelatinization periods (15 and 30 min autoclaving) for each cycle. The RS content of native starch and modified starch in 3 cycles were 2.12 and 10.91 per cent (Sugiyono, 2009). It means that repeating autoclaving-cooling cycling could increase RS yield. The resistant starch content of cassava native and modified starch is presented in Table 5.

Chemical characteristics of low glycemic functional pasta product (Noodles)

The initial moisture content of experimental products (T_1 to T_7) ranged from 8.08 - 8.17 per cent, which was less when compared to control (T_1) as 8.20 per cent. Even though the substitution with millet flour (50% and

25% kodo / barnyard millet) and cassava modified starch for the formulation of low glycemic functional pasta products reduced the protein content because of the reduction in gluten but with the addition of gum (sodium alginate) has the tendency to improve the protein content. The highest protein content was noticed in T_4 (11.20 g/100g). Manasa *et al*. (2020) reported that the protein content varied significantly with each composition. Among various trails trail-2 (12.743%) has the highest protein content followed by T1, T12. There is not much variation of all the trails, which is ranged from 11.786%-12.743%. Priyanka and Sudesh (2015) developed by-product incorporated noodles, namely Type -I (bengal gram seed coat+broken rice) and Type-II (bengal gram brokens+broken rice). Type-II supplemented noodles had significantly (P <0.05) higher (12.39%) protein content as compared to Type-I and control noodles. It might be due to high protein content of Bengal gram brokens. Fat content of all the treated pasta samples were found to be low to that of the control (2.10g/100g). This is due to the fact that the low-fat content of kodo millet and barnyard millet. The barnyard millet incorporated samples showed a very little higher fat content than the kodo millet but lower than that of the control samples. A significant increase in fiber content of pasta products (noodles) was observed with increase in the level of incorporation (50 and 25 per cent) of kodo millet flour and barnyard millet flour compared to the control. The highest fiber content was noted in T_3 and T_6 samples as 5.83 and 6.91 g/100g. Manasa *et al*. (2020) stated that the dietary fiber content varied significantly with each composition. Among various trails, trail-2 has the highest dietary fiber content, followed by T1, T3. There is not much variation of all the trails, which is ranged from 9.679 - 12.657%. These reports support the present investigation. Incorporation of millet flour and pulse flour, due to modified starch (increased resistant starch content) imparts low digestible starch content, thus products with indigestible compounds leads to slow, low rate for the enzymatic hydrolysis of carbohydrates was observed. Chemical characteristics of low glycemic functional pasta product (Noodles) were presented in Table 6.

The barnyard millet samples (41.70 – 50.12 g/100g) produced samples with lower starch content than the kodo millet flour (43.92 – 54.60 g/100g) samples. The high amylose content was noticed in T_3, T_4, T_6 and T_7 of noodles, as modified starch was added but was less in T_2 and T_5 samples due to the reduction in starch content in accordance to the incorporation of millet flour than the control. The dietary fiber of the millet and modified starch substituted product revealed an improvement in the TDF when compared to the other samples. Soluble dietary fiber was higher in the kodo millet flour substituted samples when compared to barnyard millet flour substituted samples that had higher insoluble dietary fiber. The highest total dietary fiber was noted in T_3 (19.15g/100g) and T_4 and T6, respectively. The calcium (37 to 43mg/100g), iron (3.20 to 8.01) and phosphorus (195.50 to 297.00, mg/100g), the content of all the treatments for noodles, respectively.

Organoleptic evaluation of pasta product (Noodles)

Optimally cooked pasta product (noodles) was evaluated organoleptically for various quality attributes like colour and appearance, flavour, texture, taste and overall acceptability at regular intervals initially and once in a month. Colour of the pasta (noodles) samples becomes darker (from light brown to brown) while increasing the level of millet flour and the modified starch and becomes little yellow with the incorporation of green gram dhal samples. The appearance was found to be good with the exclusion of cracked pieces, thereby the inclusion of gums. The smell (flavour) of the pasta products was without sourish or strange smell during the initial storage period. The noodles had smooth edges, while spaghetti had slightly serrated edges.

Sensory evaluation of the millet incorporated low-fat cookies

The scores for colour and appearance of T_1 and T_2 at 25, 50 and 75 per cent incorporation levels were 8.5, 8.6, 8.1 and 8.3, 8.5 and 8.1, respectively. The texture and taste ranged from 8.5 to 7.9 and 8.4 to 7.5 in T_1 and 8.2 to 8.1 and 8.3 to 8.2 in T_2 respectively which showed that the increase in incorporation levels of the millet decreased the scores. Subjective sensory characteristics of varieties of kodo, little and foxtail millet low-fat cookies are summarized in Table 7.

The flavour of the low-fat cookies showed a gradual decrease in the mean score value at increased levels of small millet incorporation. The overall acceptability showed that T_1 had8.5 and T_2 scored 8.4, which was highly acceptable at 50 per cent incorporation level. The scores for sensory attributes of T_3 showed a mean value of 8.1, 8.4 and 8.0 for colour, 8.0, 8.3 and 7.5 for flavour, 8.1, 8.2 and 7.6 for texture, 8.0, 8.3 and 7.6 for taste and 8.1, 8.3 and 7.7 for overall acceptability at 25, 50 and 75 per cent incorporation levels respectively. The above said sample was highly acceptable at 50 per cent incorporation level compared to the other three samples, which ranged from 7.5 to 8.3 for the mean-overall acceptability.

Hypoglycemic effect of functional pasta products (noodles) on alloxan-induced Wistar albino rats

The results obtained by conducting animal experiments on alloxan-induced diabetic albino rats by feeding therapeutic noodles (T_1 to T_7-Group III - IX) and compared with the normal and diabetic control rats (Group 1 & II) for 28 days (Table 8). From Table 8, it was observed that feeding the functional pasta product to rats reduced the blood glucose level after 28 days of the study period. There was a significant lowering of blood sugar level in rats fed diets in all combinations from T_1 to T_7. The dietary fiber content of kodo / barnyard millet and the modified starch (resistant starch acts as dietary fiber) contributes to the hypoglycemic effect on diabetic rats. The reduction percentage of blood glucose level in diabetic functional pasta product fed rats at 28 days of storage was observed to be 39.0 to 44.5 per cent and a comparatively higher reduction was noticed in T_4 (G6) and T_7 (G9)samples. The initial glucose level of G6 and G9 treatment group was found to be 189.50 ± 3.75and 195.12 ± 3.45and reduced to 106.12± 4.16 and 108.29± 4.40 mg/dL respectively (44.0 and 44.5 %). The protein content and its network of the samples and especially in T_4 and T_7 samples as through the green gram dhal flour contributed significant amounts, is very important in inhibiting starch digestion because it encapsulates starch granules and thus restricts the accessibility of alpha-amylase. Both the dietary fiber and protein network of T_4 and T_7 samples fed in G6 and G9 rats contributed in the hypoglycemic effect. Hegde (2005) stated that the rats fed the kodo millet-enriched diet (Whole grain flour of finger millet and kodo millet was incorporated at 55 per cent by weight in the basal diet fed to alloxan - induced diabetic rats over a period of 28 days)showed a greater reduction in blood glucose (42%) than those fed the finger millet (36%). Brites *et al.* (2011) stated that the rats fed with resistant starch enriched bread exhibited reduced post prandial glucose levels and total cholesterol. Sujitta *et al*. (2020) developed gluten free noodles prepared by resistant rice starch, XG (2.5%), inulin/defatted rice bran (5%) showed low glycemic index and high acceptability by sensory panelists. The addition of defatted rice bran and inulin increased the firmness, cooking time, protein, fiber and ash contents of gluten free noodles. This study contributed that resistant rice starch, XG, defatted rice bran, and inulin can be used as functional ingredients to formulate low glycemic index and nutraceutical gluten free foods.

Conclusion

Modified resistant starch, a retrograded starch fraction, is a useful starch derivative with therapeutic and nutritional values akin to dietary fiber. In the present study, physical modification of native starch by autoclaving was found to give a maximum yield of modified resistant starch compared to chemical modification by acid hydrolysis. Pasta and bakery products are also basic foodstuffs that have an important role in human food consumption. The research findings showed that the pasta and bakery products with lower GI and low energy density developed by adding modified starch with high resistant starch content could be a most promising solution to decrease the prevalence of metabolic disorders. It was inferred that the bread and low-fat cookies developed from wheat flour, kodo / barnyard millet flour with cassava modified starch did not affect the sensory attributes and did not change the overall acceptability of these products by consumers. These low glycemic pasta products involved a low cost of production and can ensure good returns at the manufacturing end.

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Conflict of interest

The authors declare that they have no conflict of interest.

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